SYSTEM AND METHOD FOR CHARACTERIZATION OF ELECTRICAL PROPERTIES OF THE HEART FROM MEDICAL IMAGES AND BODY SURFACE POTENTIALS

[0001] This application is a divisional of U.S. patent application Ser. No. 15/301,415, filed Oct. 3, 2016, which is a national stage (under 35 U.S.C. § 371) of International Patent Application No. PCT/US2015/023986, filed Apr. 2, 2015, which claims the benefit of U.S. Provisional Application No. 61/973,892, filed Apr. 2, 2014, and U.S. Provisional Application No. 62/021,898, filed Jul. 8, 2014, the disclosures of which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to characterization, quantification and visualization of electrical properties of the heart, and more particularly to estimating electrical properties of the heart based on an electrophysiological model of a patient from medical images and body surface potentials of the patient.

[0003] Heart failure is a major cause of death in the western world. Due to insufficient heart function, heart failure causes dyspnea and fatigue, and can also lead to cardiac arrest. Among the wide variety of cardiac rhythm disturbances, left bundle branch block (LBBB) affects approximately 25% of heart failure patients. LBBB is due to an obstruction in the cardiac conduction pathway, which decreases the speed of the electrical wave and potentially leads to dyssynchronous heart beats. For patients with a prolonged QRS-complex (e.g., QRS≥120 ms) and low left-ventricular ejection fraction, cardiac resynchronization therapy (CRT) is a well-established treatment. CRT consists of implanting electrodes in the heart to pace the muscle artificially and "resynchronize" cardiac contraction. However, 30-50% of patients do not respond to CRT despite being eligible. Hence, better patient selection for CRT is desirable.

BRIEF SUMMARY OF THE INVENTION

[0004] The present invention provides a method and system for estimating and visualizing patient-specific electrical properties of the heart from medical images and body surface potential measurements, such as classical electrocardiograms (ECG) or denser surface mapping measurements. Embodiments of the present invention utilize cardiac electrophysiology models for improved patient selection and planning of therapies like cardiac resynchronization therapy (CRT), radiofrequency ablation of atrial or ventricular arrhythmias or drug treatments. Electromechanical models can also be used without changes in the framework. To make such models clinically applicable, i.e. suitable for patient management, it is required that such models be fit to the patient patho-physiology. In other words, model parameters need to be estimated from patient data before performing virtual intervention (e.g. virtual CRT) and calculating subsequent physiology changes. Embodiments of the present invention estimate electrical parameter maps (e.g. diffusivity, action potential duration, restitution curve, etc.) of a cardiac electrophysiology or electromechanics model from medical images and electrocardiogram (ECG) or denser body surface potential mappings of the patient. While the electrical parameters can be uniform over the cardiac anatomy, embodiments of the present invention also enable the estimation of spatially varying parameters to capture local pathologies. Embodiments of the present invention then compute patient-specific cardiac electrophysiology or electromechanics simulations for therapy planning and guidance using the personalized electrical diffusivity parameters estimated for the patient.

[0005] In one embodiment of the present invention, a patient-specific anatomical heart model and a patient-specific anatomical torso model are generated from medical image data of a patient. An electrical coupling model between the patient-specific anatomical heart model and the patient-specific anatomical torso model is generated. A mechanical activation time map of the heart is generated from a dynamic cardiac image sequence of the patient. Spatially varying patient-specific cardiac electrical parameters for the patient are estimated by simulating cardiac electrophysiology over time at a plurality of nodes in the patient-specific anatomical heart model using a computational cardiac electrophysiology model and adjusting at least one cardiac electrical parameter of the computational cardiac electrophysiology or electromechanics model based on the mechanical activation time map, non-invasive electrocardiography measurements of the patient, and the simulated cardiac electrophysiology.

[0006] In another embodiment of the present invention, a patient-specific volumetric anatomical heart model and a patient-specific anatomical torso model are generated from medical image data of a patient and an electrical coupling model between the patient-specific anatomical heart model and the patient-specific anatomical torso model is generated. Extra-cellular potentials are estimated on an epicardial surface of the patient-specific anatomical heart model from measured body surface potentials on a torso of the patient based on the electrical coupling model between the patient-specific anatomical heart model and the patient-specific anatomical torso model and transmembrane potentials are estimated on the epicardial surface of the patient-specific anatomical heart model from the estimated extra-cellular potentials. Spatially varying patient-specific cardiac electrical parameters for the patient are estimated by initializing one or more cardiac electrical parameters of a computational cardiac electrophysiology model over the volumetric patient-specific anatomical heart model from the estimated transmembrane potentials on the epicardial surface of the patient-specific anatomical heart model, simulating cardiac electrophysiology over time at a plurality of nodes in the volumetric patient-specific anatomical heart model using the computational cardiac electrophysiology model, and adjusting the one or more cardiac electrical parameters of the computational cardiac electrophysiology model over the volumetric patient-specific anatomical heart model based on the estimated transmembrane potentials on the epicardial surface of the patient-specific anatomical heart model, and simulated transmembrane potentials on the epicardial surface of the patient-specific anatomical heart model resulting from simulating the cardiac electrophysiology.

[0007] These and other advantages of the invention will be apparent to those of ordinary skill in the art by reference to the following detailed description and the accompanying drawings.